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The Chinese Waterchestnut

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Cover Illustration.—Edible corms of the Chinese waterchestnut. X 3/4.

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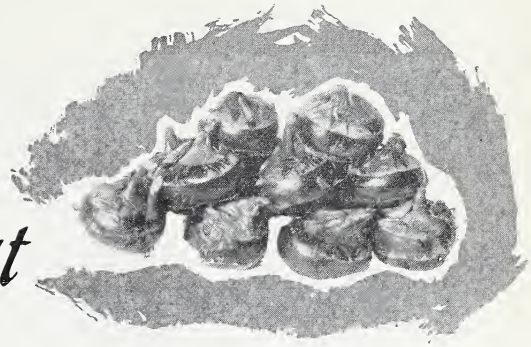
The Chinese Waterchestnut



By W. H. Hodge, *principal botanist,* and David A. Bisset, *scientific aid, Horticultural Crops Research Branch, Agricultural Research Service*

"Chinese waterchestnut" and "waternut" are English common names for a tropical sedge, *Eleocharis dulcis* (Burm. f.) Trin. (synonym: *E. tuberosa* Schult.) which is widespread in the tropics of the Old World. In the warm temperate parts of China, this species has long been cultivated for its corms, or so-called tubers. These are esteemed as a nutritious delicacy in Chinese cookery and are extensively eaten raw.

The plant is grasslike in general habit, growing to a height of 5 feet, and is cultivated somewhat like paddy rice (fig. 1). It is an important crop of southern China, and is also grown throughout the eastern part of that country as far north as Peiping.

Fairly large quantities have been imported into the United States in previous years. In 1947, the imports totaled about 2,500,000 pounds. By 1952, however, because of the embargo on shipments from China, this importation had practically ceased. The result was a shortage of this commodity, coupled with an increasing interest in establishing this type of waterchestnut as a specialty crop in the United States.

The Chinese waterchestnut is commonly known as "matai" (horse's hoof) in the Canton district and throughout the provinces of Kwangsi and Kwangtung, but elsewhere in China the Mandarin name "pi chi" (pronounced *pee chee* or *bee chee*) is used. Perhaps the chestnut-brown color of the skin, together with the chestnutty flavor and texture of the white flesh, gave rise to the English name "waterchestnut" which has supplanted the Cantonese name "matai" in Chinese restaurants catering to occidental patrons. The name "waterchestnut" is also used extensively by both American and Chinese processors of this vegetable.

Unfortunately, the same English common names, "waterchestnut" and "waternut," are also used for quite a different floating aquatic plant, the waterchestnut (*Trapa natans* L.) often called "water caltrop." This Eurasian species has become naturalized to the extent of being considered a pest in some streams in the Eastern United States (fig. 2). The leaves of this plant form floating rosettes

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FIGURE 1.—Mature Chinese waterchestnut plants, 5 feet tall, growing at the United States Barbour Lathrop Plant Introduction Garden, Savannah, Ga.

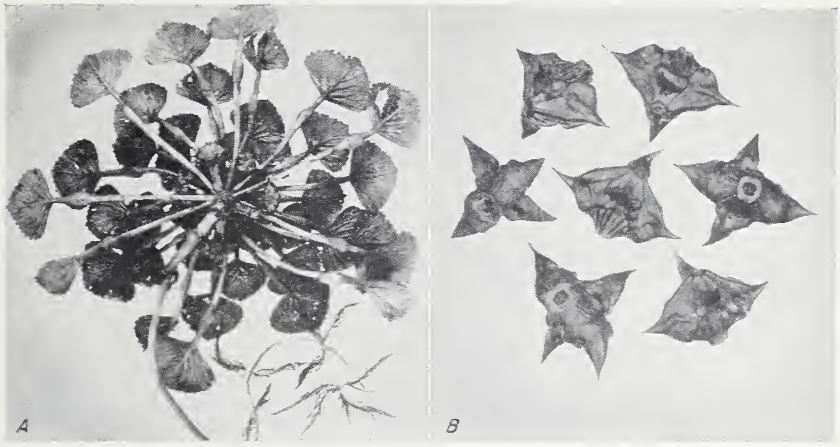

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FIGURE 2.—*A*, Mature floating rosette, 18 inches in diameter, of the waterchestnut, *Trapa natans* L. (also called "water caltrop"), an aquatic pest often confused in name with the Chinese waterchestnut; *B*, the four-horned, nutlike fruit.

which can hardly be confused with the upright leafless green stems of *Eleocharis dulcis*. Although the seeds of *Trapa* can be eaten, the characteristic four-horned fruits in which they are borne are quite distinct from the highly edible corms of *Eleocharis*. In view of this apparent confusion between plants, the Cantonese name "matai" has been recommended for use in the United States; however, the name "waterchestnut" is so firmly established that it seems impossible to supplant it. Under the circumstances, it seems best to distinguish between these two distinct plants by calling the economically valuable *E. dulcis* the "Chinese waterchestnut."

Botanical Description

In its general habit, *Eleocharis dulcis* resembles other species in this large genus of the sedge family (*Cyperaceae*). Characteristic of the plant is its lack of leaves, their photosynthetic function having been transferred to the numerous upright tubular septate stems. Under cultivation these run from 3 to 5 feet tall.

Insignificant flowers are produced among tiny imbricated scales located at the tip of the stems (fig. 3). Male and female flowers are produced but not concurrently. The female (pistillate) flowers appear first when the stem tips are 5 or 6 inches above the water level. Considerably later, after the stems have attained a height of about 24 inches, male (staminate) flowers appear in the same inflorescences. Tiny "seeds" (actually achenes) are produced, but these are of no importance in the culture of the plant as a crop.

Even in the wild state, *E. dulcis* apparently reproduces mainly through the vegetative production of subterranean rhizomes and corms. Rhizomes are of two types and are easily distinguishable. One, appearing early in the growth cycle (usually from 6 to 8 weeks after planting) serves to multiply the individual during the current

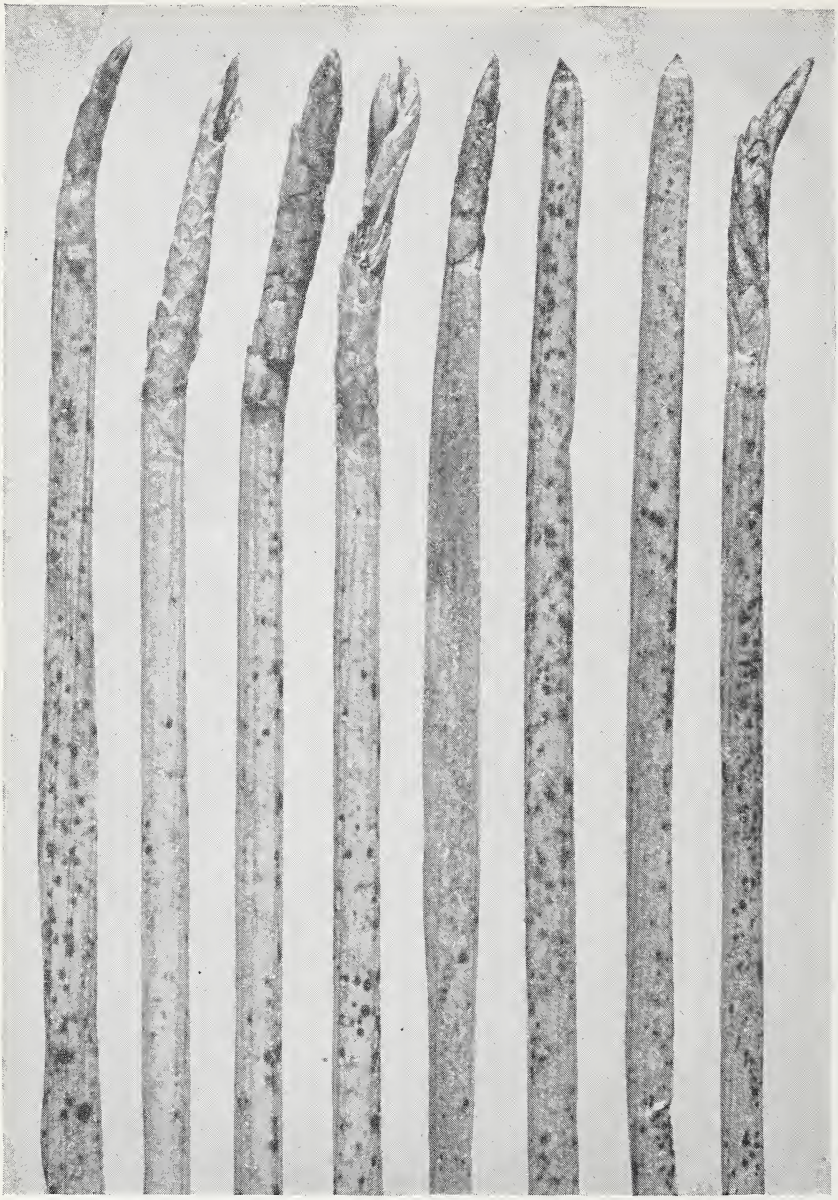

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FIGURE 3.—Dried Chinese waterchestnut stems, showing inconspicuous flowering structures at tips. (The spotting of the stems is caused by saprophytic fungi not present on the living plants.)

growing season through the lateral production of a number of daughter plants (fig. 4). Another rhizome type appears much later in the season, shortly after flowering. This type is produced by the mother as well as by all the daughter plants and is the important producer of corms which develop at their tips (fig. 5).

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FIGURE 4.—A Chinese waterchestnut plant (center) and the secondary plants produced by it early in the season through the growth of underground rhizomes.

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FIGURE 5.—Corms and corm-producing rhizomes as they appear on a Chinese waterchestnut plant at the end of the growing season.

Waterchestnut corms usually are abundantly produced. In size and form, they bear a superficial resemblance to the corms of the garden gladiolus, being brown-skinned, subglobose, and vertically compressed, but the firm, white flesh inside is unusually crispy, like that of an apple (fig. 6).

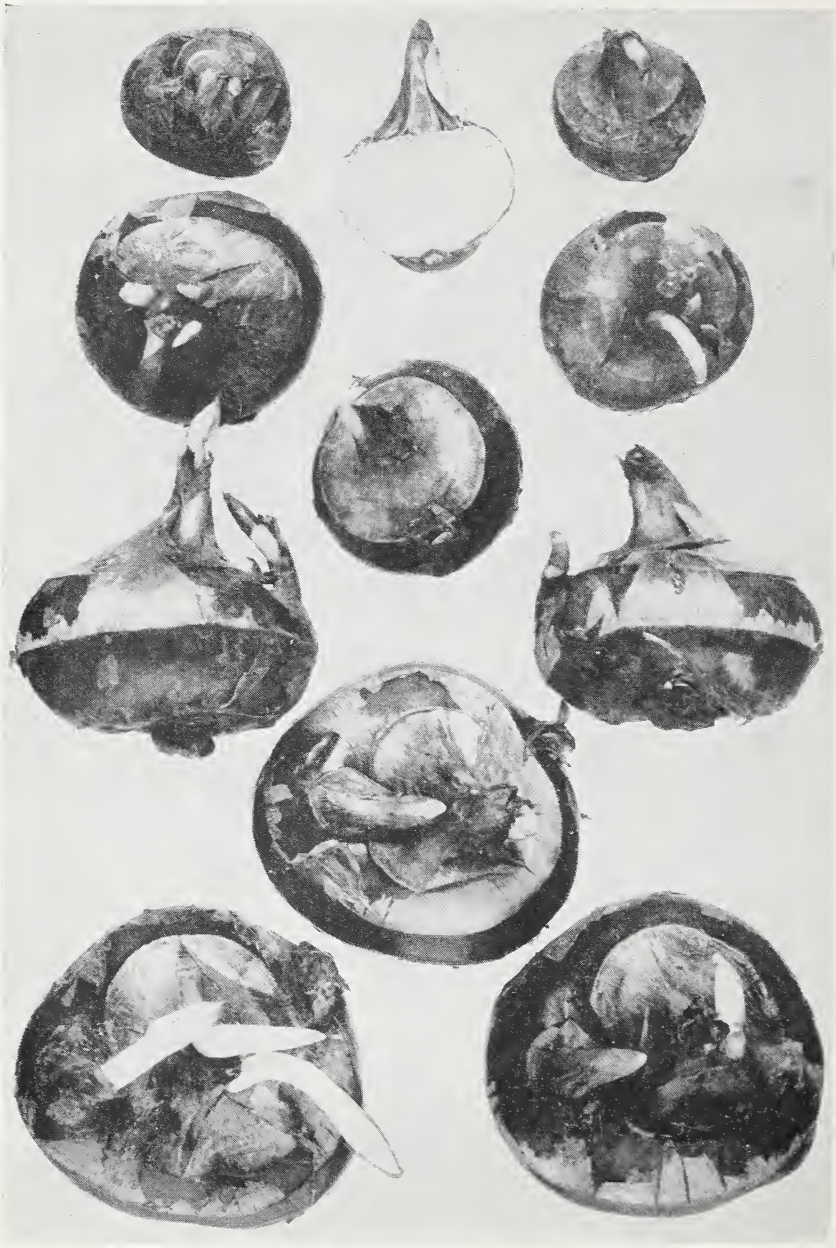

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FIGURE 6.—First-class Chinese waterchestnut corms (life-size); the top-center corm is shown in section. All are marketable except the smaller corms in the top row.

Introduction Into the United States

A superior variety known in southern China as "hon matai" was introduced by the Plant Introduction Section of the United States Department of Agriculture from Canton in 1934. This is the only type of Chinese waterchestnut now planted in the United States. This introduction (P. I.[1] No. 106274) was first grown at the United States Barbour Lathrop Plant Introduction Garden, Savannah, Ga., where, over a period of years, plantings have been made to determine cultural requirements, and also to make propagation material available for evaluation in other areas (fig. 7). "Hon Matai" has since

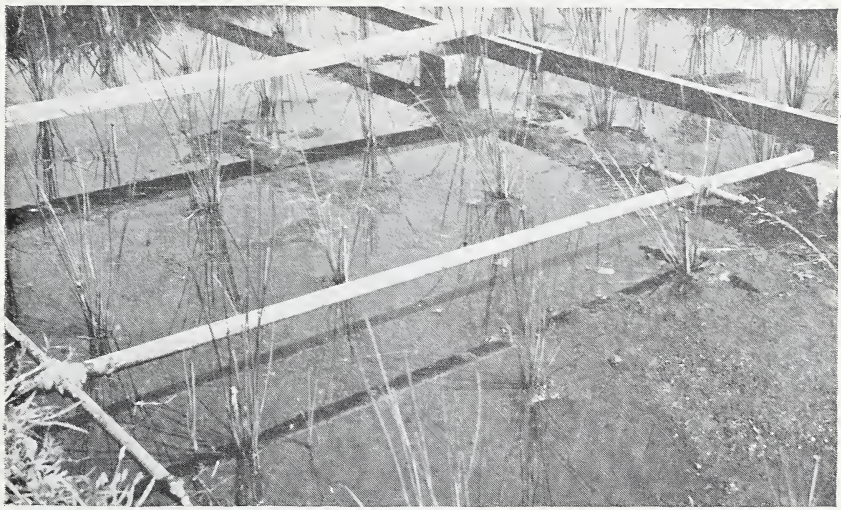

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FIGURE 7.—Test plots of Chinese waterchestnuts at the United States Barbour Lathrop Plant Introduction Garden, Savannah, Ga. Several of the plants have already produced laterals through the growth of rhizomes.

been tested in a number of localities in the South and on the Pacific Coast. These tests show that the plant can be successfully grown in this country. To date the best results have been obtained in the southern areas of the Atlantic Coastal Plain. Plantings in northern areas have been unsuccessful because of the lack of a long, frost-free season. The coastal section around Norfolk, Va., seems to be about the northern limit for the successful commercial culture of Chinese waterchestnuts.

Cultivation

Chinese waterchestnuts may be grown as an annual crop, under controlled irrigation, in warm temperate regions where there is a lengthy frost-free growing season of approximately 220 days. They are not a crop for swamplands or marshlands, unless such lands are fitted with banks and ditches to control water levels and facilitate

[1] P. I. refers to accession number of Plant Introduction Section.

drainage for harvesting and preparation of the land. Complete details of culture have not been fully determined, but tests made at Savannah, Ga., indicate that the best planting time in the South is in March or April. In general, plantings should be made 2 to 3 weeks before the date of the last killing frost. In the spring, young plants are seriously injured by freezing temperatures.

Planting should be made in level, fertile soil with the plot surrounded by low banks or dams, making possible the retention of 4 to 6 inches of water over the entire field (fig. 8). Such soils as muck soils, which

PI-NEG. 33,212

FIGURE 8.—A ¼-acre plot of recently planted Chinese waterchestnuts at the United States Barbour Lathrop Plant Introduction Garden, Savannah, Ga. Water was maintained at a depth of approximately 5 to 10 inches by the overflow from an artesian well.

are rich in organic material, are favored, but they should be tested to determine their acidity. Chinese waterchestnuts do not seem to do well in acid soils, and such difficulties as have been encountered to date with this new crop have been associated with overacid conditions. The pH should run between 6.9 and 7.3 Ground limestone may be added to or broadcast over the soil as an aid in correcting acidity.

Corms used for seed purposes should be selected to insure soundness, freedom from injury, and intact terminal bud, and they should be of good form. Observations at Savannah indicate that, although a crop can be produced from small seed corms, superior growth and production may be expected if large corms are planted. To counteract drying out or sprouting prior to planting, propagation stock should be kept cool and moist. Storage temperatures ranging between 30° and 40° F. will keep the corms reasonably dormant.

Depending on the latitude, one of two methods of planting may be used. In northern plantings, at about the latitude of Norfolk, Va., where the growing season is shorter, corms may be started early in protected seedbeds or nursery plots where the necessary growing temperature of approximately 60° F. can be maintained. Such beds should be well prepared. The corms are planted about 2 inches deep and are spaced 4 to 6 inches apart in each row, while the rows are spaced 6 to 8 inches apart. Following planting, the bed is flooded to settle the soil, after which the water is withdrawn. The grasslike stems will appear following a germination period of about 10 days.

When the plants are about 8 to 12 inches high, they should be transplanted to the permanent field beds or plots. This is a hand operation, requiring the careful moving of each young plant to its final field position. If the soil of the seedbed is first softened by flooding, the young plants can be removed much more easily. By carefully placing a hand under the seed corm and raising the corm and plant vertically, the entire plant and its root system can be lifted with little injury. Such started plants should be set 30 inches apart, in triangular arrangement, in prepared plots that are kept flooded thereafter with 4 to 5 inches of water (see fig. 7). Careful handling of plants of this type should insure the establishment of 95 percent or more of the young transplants.

In southern plantings, at about the latitude of Savannah, Ga., and points south, the seedbed and transplanting procedure described above may be followed, or corms may be planted directly in permanent field plots. For permanent planting, corms should be planted 4 to 5 inches deep and 30 inches apart in rows that are similarly spaced. In small plantings, seed corms may be set by hand in holes dug with a hand trowel. The corm is placed in the bottom of the hole and covered with loose soil, which need not be firmed or packed. In large plantings, furrows may be opened with an opening plow or colter, and the corms dropped in the furrows at 30-inch intervals. They can then be buried with a covering plow or hiller.

After planting, the entire plot or field should be flooded and kept submerged for a day, after which the water supply should be shut off and the water in the plot or field allowed to settle and drain naturally. This initial flooding settles the soil around the newly planted corms and facilitates the establishment of the young plants. As soon as they are 8 to 12 inches high, the planting should again be flooded and kept flooded with 4 to 5 inches of water throughout the remainder of the growing season.

Weeds have not proven to be a problem in the culture of Chinese waterchestnuts, especially if the soil is tilled a day or so before plantings are made. If weeds become established in the plots after the corms are planted, they should be removed before the plots are flooded permanently. Any subsequent weeding should be done in such a manner as to avoid unnecessary trampling or packing of the prepared soil.

Under favorable conditions, plants develop rapidly, and in 6 to 8 weeks' time, rhizomes will be growing out from the base of the original plant, giving rise at their tips to secondary plants which appear at varying distances from the parent.

Chinese waterchestnut plants continue to grow throughout the summer season, the many lateral rhizomes producing secondary plants in such numbers as to hide or cover the soil and floodwater completely with a dense mass of tubular, leaflike stems (see fig. 1). The tips of the stems often die back a bit, becoming brown during the growing season, but this is a normal decline and is to be expected. Following the completion of the flowering period in late summer, all the plants form corm-producing rhizomes. The crop of corms usually reaches maximum size between early fall and the first heavy frost. At the close of the growing season, there will be corms in all stages of development. Fully mature corms are chestnut brown in color, whereas immature corms are whitish. Corms should be left in the ground as long as possible so that the immature ones can mature properly.

At the latitude represented by Savannah, Ga., the first killing frost usually comes in the last half of November. Water should be drained from the planting approximately 30 days before this killing frost or at the time when the plants have attained maximum maturity. Removal of the water serves to hasten maturity of the corms and also aids in the harvest by providing a drier, more easily handled soil.

As soon as the stems are dry, they should be removed either by burning or cutting, for if left on the plot they serve as a protected retreat for rodents which may dig down and cause serious havoc with the crop.

The dry stems, when harvested, have proven useful in several ways. They are eaten readily by cattle; they make an excellent mulch or a superior compost; and they can be utilized as packing material for the shipment of plants.

Fertilizing

Chinese waterchestnuts require large amounts of plant food; and on average soils, heavy applications of high-grade, complete fertilizer, such as would be used for other vegetable crops, should be added. Applications at the total rate of 1 ton per acre have promoted maximum production. Approximately one-third or one-half of this total should be applied to the soil during the preparation for planting. Fertilizer can be broadcast and stirred into the soil with tillage operations. Organic manures can also be applied to the soil before preparation; however, such fertilizer should be well rotted before application and should be applied 2 to 3 weeks in advance of the planting date.

Another application of fertilizer (one-third or one-fourth of the total application) should be made about 8 to 10 weeks after planting, or at the time that the first of the secondary plants, produced by the parent, are appearing. For this application the beds should be drained and the fertilizer broadcast over the plot when the plant stems are dry, to prevent "burning" or similar injury.

The balance of the fertilizer should be applied during the last half of August, prior to the initial development of the young corms. Inasmuch as the developing rhizomes are tender and easily broken, no walking or moving of equipment should be attempted in the plot after plantings are established, for such traffic would injure considerable numbers of the developing young rhizomes.

Harvesting

Approximately 20 to 30 days after the first killing frost, or after the plants have attained maximum maturity, harvest of the crop may be started. At such time, practically all the corms are full grown and have assumed the chestnut-brown color typical of mature corms of the variety "hon matai." If desirable, some corms may be dug as soon as the plants attain maturity, but at such an early harvest date there will be a considerable number of immature white or light-colored corms. These young corms are not so sweet and palatable or so suitable for cooking as those which have fully matured underground, nor are they so acceptable to the trade. Where winters are mild, as at Savannah, Ga., the crop may be left in the ground, to be dug as needed.

Because of the heavy and compacted nature of the soil in which they are grown, Chinese waterchestnuts are not easy to harvest. In small plantings, corms are dug most easily with handtools. A spading fork is well suited for this purpose, and when such a tool is used, the soil is turned carefully and the corms are picked out by hand. Care should be taken to avoid bruising the corms with the digging tool.

A ¾-inch mesh screen, laid horizontally on supports, is useful in harvesting small plots (fig. 9). The soil is carefully lifted onto the screen and worked over with rubber pads or paddles. Approximately

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FIGURE 9.—Harvesting a small Chinese waterchestnut planting at the United States Barbour Lathrop Plant Introduction Garden, Savannah, Ga. Soil is screened as dug, the corms being dropped into water in the large container.

98 percent of the corms will remain on the screen as the soil is worked through. These are picked up and dropped into a bucket or other container filled with water. This method not only prevents the bruising that would occur from dropping corm upon corm, but it also helps remove excess soil. Although such harvesting methods may seem laborious, the labor cost involved is not excessive providing there is a good production of corms.

In larger field plantings, corms may be harvested advantageously by use of a small plow that turns a furrow to a depth of approximately 6 inches. Each furrow should be raked with a potato rake, the tines of which have been covered with soft rubber tubing; the ends of the tines should preferably be sealed with the rubber. As the corms are picked up, they are carefully placed in containers and then carried to a suitable washing device for the removal of excess soil and debris.

After careful washing, the corms are placed in shallow trays to dry. Slow drying in shade is preferred to sun-drying. When no moisture remains on the surface of the corms, they can be packed for shipment or prepared for storage.

For special harvesting and handling precautions for corms that are to be stored, see section on storage (p. 13).

Diseases and Pests

Chinese waterchestnuts are still too new a crop in this country to have provided much information regarding potential diseases or pests.

Already mentioned under "Cultivation" (p. 8) is the apparent necessity for a proper pH level in soil in which the waterchestnuts are to be grown. The only difficulties so far reported in the culture of this specialty crop seem to be associated with acid soils. Sometimes plants grown under such conditions undergo gradual deterioration about the time of flowering. In this weakened state, they may be more subject to attack by disease. The only pathogen reported for this crop is a stem fungus (*Cylindrosporium* sp.) found attacking plants growing on a soil of high acidity (pH 5.5).

At present the most serious insect pest is the billbug, *Calendra cariosa* (Oliv.), a species that generally feeds on native sedges. It has damaged test plantings of the waterchestnut in central Florida.

In one planting in Florida, Chinese waterchestnuts have been observed being attacked by a stem nematode, *Ditylenchus* sp., and by the awl nematode, *Dolichodorus heterocephalus* Cobb. However, the pathogenic significance has not been determined, and control procedures are unknown.

Rodents, especially rats and muskrats, relish waterchestnut corms and thus are a potential threat to the crop, especially if the plantings are near the natural haunts of these animals. The cutting-off or burning of the stems, once the mature waterchestnut plot has been drained and dried off in the fall, makes the crop less inviting to such pests by destroying their shelter from natural enemies. It is conceivable that if allowed to burrow in the retaining banks, such rodents, as well as crayfish, might also interfere with the maintenance of the water level required for this crop by honeycombing these banks. Regular patrolling of the banks of the plots is usually sufficient to drive off such pests.

Yield and Marketing

In suitable locations and with liberal applications of organic or other fertilizers, good yields should be expected from this crop. In southern China, yields are reported ranging from 2,700 to 5,000 pounds of corms, mainly of good size, from ⅛-acre plots. The maximum production on trial plots at Savannah, Ga., has been approximately 1$\frac{1}{10}$ pounds per square foot, or about 47,000 pounds per acre. Under good growing conditions, 1 plant (representing the mother and all daughter plants produced in a season from a single planted corm) has produced 20¾ pounds of corms. Such a plant occupies an area of about 25 square feet at harvesttime.

Marketability

Corms vary considerably in size and, under good conditions of growth, may measure as much as 45 mm. in diameter. In general, only corms 30 mm. ($1\frac{3}{16}$ inches) or more in diameter are acceptable to the trade. About 60 percent of the yield is usually marketable. Smaller corms (20 to 30 mm. in diameter) can be saved for seeding purposes; but any surplus can be used for special purposes suggested in the section on utilization (p. 14). Corms damaged or bruised during digging may be salvaged and canned.

Market Prices

Around 1952, following the embargo on imports from the Chinese mainland, increasingly attractive prices were offered for homegrown Chinese waterchestnuts. By 1954, the prices paid to small domestic growers in the United States ranged from 35 to 80 cents per pound, as compared with prices of 30 to 40 cents received for corms still being imported from Formosa.

Storage

Although fresh corms of Chinese waterchestnuts are preferred by the trade, corms can be satisfactorily stored for market purposes if containers are used that are reasonably tight but not airtight.

Before storage, the corms should be graded to remove all broken or damaged individuals and then washed in clear water to remove soil and foreign matter. They should then be air-dried until all surface moisture is removed. After drying, the corms should be carefully packed in moistureproof containers, but *not sealed airtight.* Containers holding approximately 16 gallons are convenient and easily handled. The commercial storage temperatures should be between 30° and 40° F., the range commonly used for storage of apples, celery, and lettuce. Corms packed and stored in this manner have been kept successfully for 6 months.

For home purposes, Chinese waterchestnuts can be washed, dried, and placed in mason jars, with lids applied *but not sealed,* and the filled jars kept in the home refrigerator. If storage temperatures are too high, sprouting of the waterchestnuts may occur. Some experiments have been made with storage in plastic bags, which seem suitable for holding corms for short periods in the home refrigerator *provided the bags are not sealed tight.*

Chinese waterchestnuts cannot be kept successfully in open storage, for they soon begin to shrivel and in a few days become worthless for home use.

It should be emphasized that the most careful harvesting and handling methods and procedures should be used, to avoid bruising or injuring the corms that are to be stored. When the corms are mature, they are turgid and are thus susceptible to injury by bruising, dropping, knocking, and other kinds of rough handling. Sound, unbruised corms can be stored for much longer periods than corms that have not received careful handling during digging and harvesting.

Experiments at the Barbour Lathrop Plant Introduction Garden have shown that mature corms can be left in the soil for several months after maturity, that is, during the winter months of December, January, and February. Under such natural storage conditions, the temperature of the soil should be observed; and if the soil temperature rises above 56° F., the corms should be examined to determine whether sprouting has begun. If sprouting is detected, the crop should be dug and disposed of, or stored under refrigeration to retard sprouting.

Processing

Although Chinese waterchestnuts are in greatest demand in the fresh form, interest is developing in standardizing procedures for processing them by canning and freezing. Corms to be processed are first peeled. Hand peeling is done in the canning plants of the Orient where labor is cheap. The flattened shape of the corms makes them difficult to peel by standard mechanical means, and no completely satisfactory new method of peeling has been devised. A plate of hand-peeled corms is shown (fig. 10).

The National Canners Association recommends processing periods for Chinese waterchestnuts similar to those for white potatoes. The recommended commercial-canning temperature would be 240° F. after an initial temperature of at least 140° F., with the following processing periods for the can sizes designated:

Size of can:	*Minutes*
No. 2	30
No. 2½	35
No. 10	45

For home canning in glass jars, waterchestnuts should be processed, 30 minutes for pints and 40 minutes for quarts, in a steam canner at 10 pounds pressure and a temperature of 240° F.

Corms to be frozen are held at standard freezer temperatures. In general, canned waterchestnuts lose much of their flavor but retain their crispness, whereas frozen waterchestnuts retain the flavor but are less crisp than the canned product.

Utilization

The corm of the Chinese waterchestnut has a crisp, white, applelike flesh that is both sweet and starchy. Some users find the flavor and texture of the uncooked corm similar to that of fresh coconut rather than the true chestnut. The total solids approximate 22 percent, of

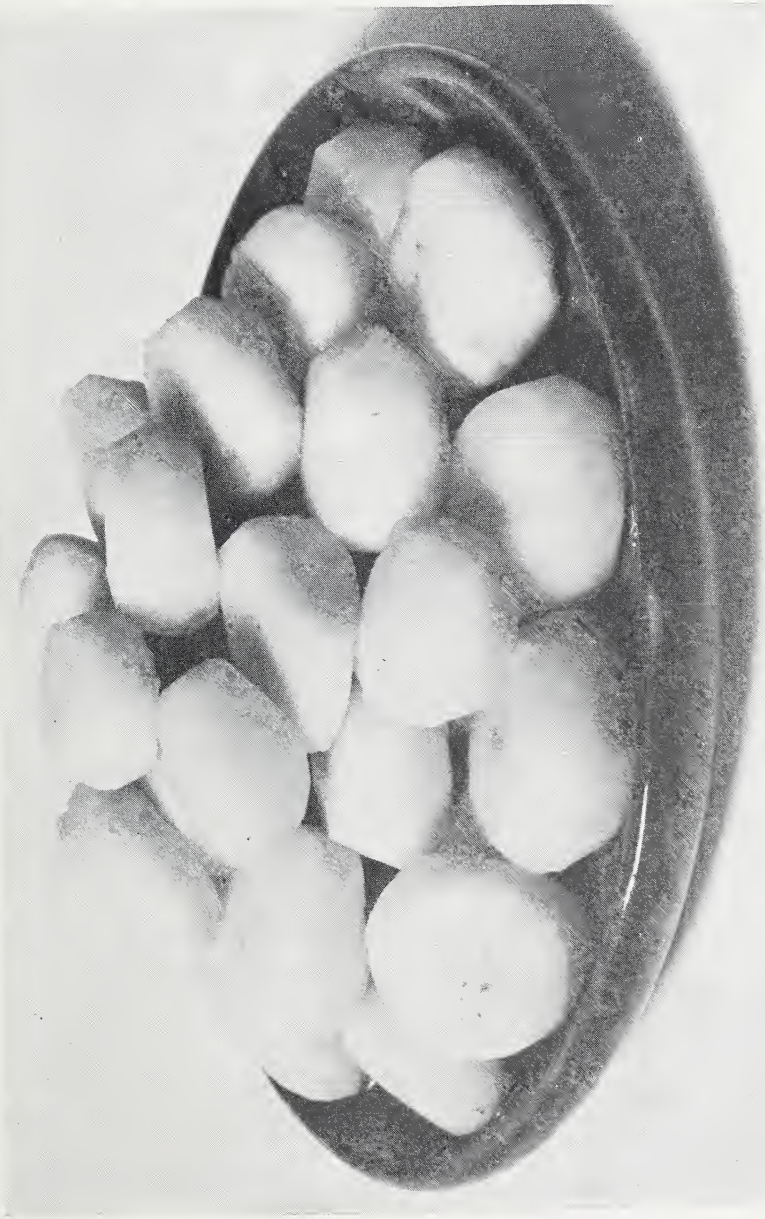

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FIGURE 10.—Pared and canned Chinese waterchestnuts, ready for use.

which about 1.4 percent is protein, 19 percent carbohydrate, and the fiber less than 1 percent.[2]

The vegetable is used best in combinations and seems to blend well with almost any food. It has been used satisfactorily in a number of American dishes, such as omelets, gravies, all kinds of meat and vegetable stews, soups, macaroni-and-cheese en casserole, and mixed salads. In contrast to the behavior of most common vegetables, which soften under cooking, the corms fully retain their crisp texture when cooked—a texture that adds an excellent quality to the dish in which they are used.

Chinese waterchestnuts, especially the smaller corms which are not marketable, can also be used for various types of unusual, high-quality pickles. The crisp texture enhances the tastiness of such preparations.

Surplus small corms (see p. 13) are suitable for use, not only as pickles, but also as feed for livestock—especially fowl, which relish these corms greatly.

Waterchestnuts are standard ingredients of most Chinese dishes, and in the Chinese restaurant trade they are much in demand. The growing popularity of Chinese foods and their increasing use by the canning and frozen-food industries in the United States suggests even greater demand for this unusual Chinese vegetable.

When prepared for the home table, the corms are pared and usually sliced about ⅛ inch thick before being cooked. Paring is facilitated if a slice is taken from the bottom and from the top of the corm, after which the epidermis can be removed from the sides (see fig. 10). When cooked separately from other foods, Chinese waterchestnuts are boiled in slightly salted water. The cooking time required for the sliced corms is rather short—not over 15 minutes—and even partial cooking is often entirely satisfactory.

For omelets and other dishes requiring a very short cooking period, corms are best shredded; if sliced, however, they should be sliced very thin, then cut up into small pieces.

[2] Leung, Woot-Tsuen Wu, Pecot, R. K., and Watt, B. K. composition of foods used in far eastern countries. U. S. Dept. Agr. Handb. 34, 62 pp. 1952. [Processed.]

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